MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

ERT3036 – ADVANCED ROBOTICS

(RE)
(OPEN BOOK EXAMINATION)

24 FEBRUARY 2017
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of **6 pages** including cover page with **4 Questions** only.

2. Attempt **ALL** questions. The distribution of the marks for each question is given.

3. Please write all your answers clearly in the answer booklet provided.

Question 1

(a) The position of a differentially driven wheeled mobile robot is represented by point ***P***. ***P*** is located at the mid-point along the axis connecting the two motors. The width between the two motors is w = 0.5m and its length is L=1m. The mobile robot is currently located at coordinates (2m, 2m) and it is going towards its goal at point ***G*** (5m, 5m).

Circular obstacles with radius of R = 0.5m are located at point T_1 (4m, 3m) and T_2 (2m, 3.5m). At this point, $R+S+L$ = 3.5m and $R+S+2L$ = 4.5m.S is the minimum distance of which mobile robot must stop in front of the edge of the obstacle before colliding with it.

At this instant, $\vec{PG} = \begin{bmatrix} 3.5 \\ 35 \end{bmatrix}$; $\left\|\vec{T_1P}\right\| = 2.58\,\text{m}$ and $\left\|\vec{T_2P}\right\| = 2.5\text{m}$.

Find the navigation vector for the mobile robot at this point. **[12 marks]**

(b) Find the ratio of v_1/v_2 for a differential drive mobile robot with the trajectory for wheel 1 (point A to point D) as shown in **Figure Q1.(b)**. v_1 is the velocity of the left wheel (wheel 1) and v_2 is the velocity for the rigid wheel (wheel 2). The width if the robot is w = 0.4m. **[8 marks]**

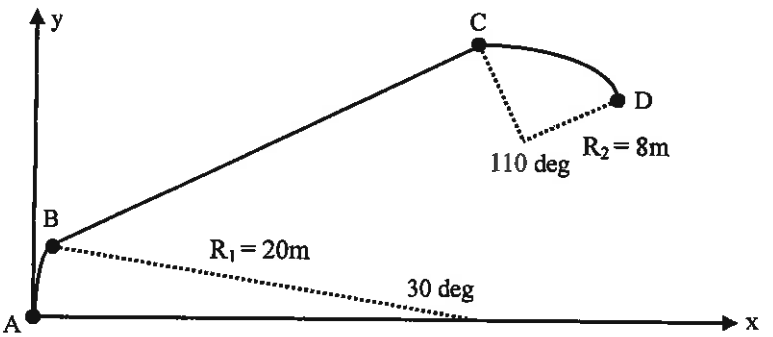

Figure Q1.(b). The Trajectory for wheel 1 from point A to Point D

(c) Draw the block diagram of the Extended Kalman Filter (EKF) and explain the physical meaning of each of the parameters and symbols.

[5 marks]

Continued ...

Question 2

A Kuka KR Agilus robot arm is a 6-axis robotic arm as shown in **Figure Q2.** When the arm is rotated to align with the saggital plane, it is actually a two-link arm in the x-z plane if we do not consider the end effector.

The equation of motion for a two-link arm in saggital plane pivoting at the origin $(x,z) = (0,0)$ can be derived using Lagrange formulation. Assume that for link 1 its length is l_1, mass is m_1 , moment of inertia is I_1; and for link 2, the length is l_2, mass is m_2 , and the moment of inertia is I_2.

(a) Find the square of the velocities of the centre of mass for both link 1 and link 2, ie

$$\dot{x}_1^2 \ , \ \dot{z}_1^2 \ , \ \dot{x}_2^2 \ \text{and} \dot{z}_2^2$$ **[11 marks]**

(b) Evaluate the kinetic energy, K_1 , K_2 for link 1 and link 2; then express the potential energy for both link 1 and link 2, P_1 and P_2. **[7 marks]**

(c) Using Lagrange formulation, derive the equation of motion for the robotic arm. **[7 marks]**

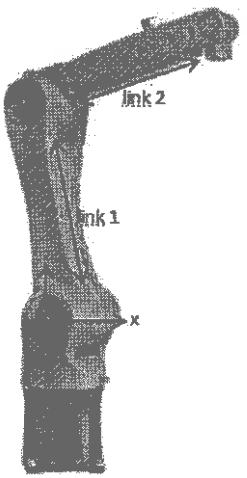

Figure Q2. A 6 Axis Kuka KR Agilus Robot Arm

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Question 3

A DJI F450 quadcopter is shown in **Figure Q3** with the mass, $M = 0.5$kg, $k = 6\text{x}10^{-8}$ N/(rpm)^2 and $g = 9.81$ m/s^2.

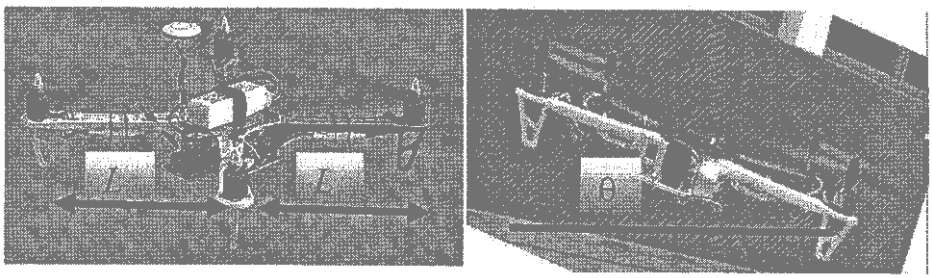

Figure Q3. (Left) The quadrotor is hovering. (Right) The quadrotor is moving to the right

(Picture Source: http://www.rcgroups.com/forums/showthread.php?t=1901564)

(a) When all four motors are rotating at same speed, ω , the quadrotor is hovering. Find ω in rpm. **[5 marks]**

(b) When the quadrotor is making an angle θ with the horizontal plane, it moves along the x-axis to the right as shown. If the gravity force is still compensated with all the rotors are having the same speed at ω_m, and the acceleration in the x direction, $a_x = 2$m/s^2, find the angle θ and ω_m. **[8 marks]**

(c) Briefly describe how you can change from hovering to moving to the right for this quadrotor. **[5 marks]**

(d) When $T_1 = T_2 + \Delta T$, $T_2 = T_4$ *and* $T_3 = T_2 - \Delta T$, how much time is required to reach the desired tilt angle as in (b) when the moment of inertia for the quadrotor is $J = 0.0025$ kgm^2, $L = 0.225$m and $\Delta T = 5.07\text{x}10^{-4}$ N? **[7 marks]**

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Question 4

(a) **(i)** Kismet is a sociable robot, as shown in **FigureQ4.a(i)**, created by Professor Cynthia Breazeal from MIT's Media Lab. It can display emotional states through facial expressions. Describe how this was done using the 3 dimensions of its affection states. **[6 marks]**

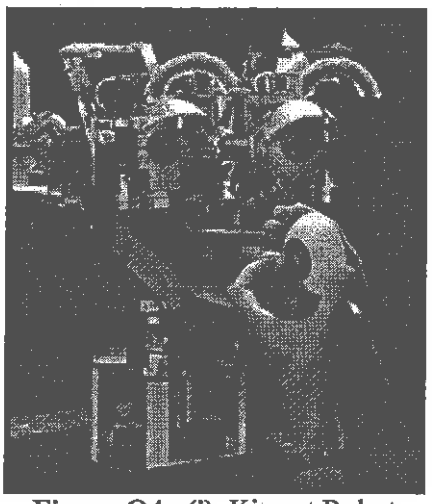

Figure Q4.a(i). Kismet Robot
(Source: http://www.ai.mit.edu/projects/sociable/baby-bits.html)

(ii) A school in our community is going to introduce NAO robot, as shown in **FigureQ4.a(ii)**, as the Social Assistive Robot (SAR) programme in an attempt to reduce human workload. You are requested to elaborate on some ethics issues or potential problems on this initiative before its actual implementation. **[6 marks]**

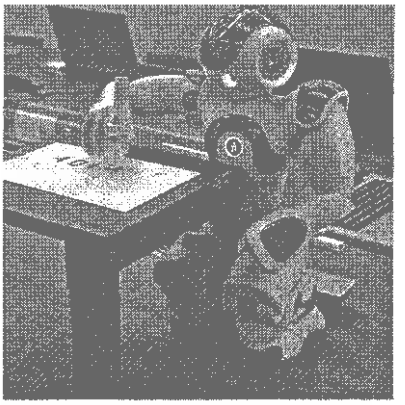

Figure Q4.a(ii). NAO Robot
(Source: http://www.ibtimes.com.au/south-australian-schools-use-robots-assist-teachers-improve-curriculum-world-first-study-1460749)

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Question 4

(b) A fictitious humanoid robot is playing one-on-one basketball with a human player. The robot is trained in 4 moves: Jump Shot, Spin, Euro Step and Up & Under. For each move, there are 3 attempts for training purpose. The robot is programmed to learn and make decision based on Q-learning algorithm after the 12 training attempts.

(i) Complete the Q-learning **Table Q4.(b)** by finding the values of the updated Q, when learning rate, $\alpha = 0.5$ and the discount rate, $\gamma = 0.4$. Reward, R, for each made basket is given and there is no reward if the robot did not make the shot. **[10 marks]**

(ii) Based on the 12 attempts, which move will the robot make in the 13th attempt? Please justify your answer. **[3 marks]**

TableQ4.(b) Q-learning Table

				Jump Shot	Spin	Euro Step	Up & Under
			Reward, R	100	50	80	20
Attempt	Move	Made	Q	0	0	0	0
1	Euro Step	1		50			
2	Euro Step	0		35			
3	Euro Step	0		Q_1			
4	Spin	1			25		
5	Spin	1			Q_2		
6	Spin	1			Q_3		
7	Jump Shot	1				40	
8	Jump Shot	0				Q_4	
9	Jump Shot	1				Q_5	
10	Up & Under	0					0
11	Up & Under	0					0
12	Up & Under	1					10

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